Evaluation of Cold Dwell Fatigue

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The primary objective of this program is to develop a fundamental understanding of the minimum combinations of stress and temperature that are required to induce dwell fatigue failure in the commonly used alloy Ti-6Al-2Sn-4Zr-2Sn (+Si). Materials being examined have the representative lamellar and globular alpha/beta microstructures. The proposed research will be carried out in two phases. The primary objective of the first phase is to produce micro-tensile and micro-fatigue samples of Ti-6242 whereby the constitutive behavior of the individual microstructural elements of the material can be characterized independently. Processing methods have been developed that permit creation of single colony, bi-colony and multi-colony micro-tensile specimens of Ti-6242, with both lamellar and globular alpha/beta microstructures. Creep, cyclic fatigue and variable-dwell-fatigue are being conducted on the micro-tensile/fatigue samples as a function of crystallographic orientation, as well as hydrogen content in order to determine the effect (if any) of hydrogen on transient creep behavior, the critical local strains for crack initiation, and the growth laws for crack propagation. Using this constitutive information, microstructural finite-element models are being developed to predict of local stress concentration evolution, nucleation and propagation of cracks (including interactions of cracks with phase and grain boundaries), and final onset of catastrophic failure in single-colony and multi-colony crystals. These models will also enable exact features of grain structure and local texture to be incorporated for simulation of polycrystalline structures, and with the goal of being integrated into a hierarchical computational system compatible with the commercial FEM codes utilized by the engine companies. The accuracy of the predictions of dwell-fatigue behavior will be validated by comparison with experiments on laboratory-scale, polycrystalline samples.

There has historically been an issue in correlating the occurrence of Dwell Fatigue in field hardware with the results of laboratory tests. That is, Dwell Fatigue cracks have been found in hardware that operates at lower stresses than the apparent threshold stress for dwell fatigue in laboratory tests. Conventional wisdom holds that this is because the stressed volume in real hardware is much larger and, statistically, it is more likely to have a ìworst caseî microstructural region that is aligned with the maximum stress. The small specimens used in this program will allow direct determination of the magnitude of the worst case microstructure effect. The relative rankings will be useful in determining the microstructural conditions that should be avoided in real hardware. This ranking has not been possible in tests using polycrystalline specimens and thus the complementary contribution of the small specimens is considered essential.

This presentation will describe the progress made to date in this program and indicate the direction of the future planned research.